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AUTHORITY

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Report No. 1

1. Title: Legibility of aircraft instrument dials: the relative legibility of manifold pressure indicator dials.

2. Object: To obtain objective data that will provide specifications for optimum legibility of aircraft manifold pressure dials.

3. Conclusions and recommendations:

a. With ultraviolet light the standard manifold pressure indicator dial (AC Type D-10) exhibits an improved legibility when the small numbers at the mid-division marks are obscured.

b. A manifold pressure dial with 1/4 inch numbers is superior to a dial with 3/16 inch figures. It appears desirable to compress the width of the numerals in relation to their height in order that the association between a particular number and its appropriate division mark is of optimal clarity.

c. It has been demonstrated that the starting point of a scale can be shifted considerably without affecting the dial's legibility.

d. Within certain limits, the legibility of a dial appears to be closely associated with the angular spacing of the division marks. Two scales which have a difference in the angular spacing of the division marks that is only about one and a half degrees exhibit a statistically significant difference.

Report by:
Roger B. Loucks
ROGER B. LOUCKS, Ph.D.

Approved:
[illegible]

27TH AAF BASE UNIT
AAF SCHOOL OF AVIATION MEDICINE
RANDOLPH FIELD, TEXAS

Project Report

Project No. 325 7 December 1944

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Discussion:

In this series of studies the relative legibility of a dial is considered to be indicated by the accuracy with which a series of pointer settings can be read during brief exposures. In any comparison of a pair of aircraft instruments, the dial which yields the fewer errors is considered to be the more legible. The experimental routine for these studies has been described in Reports No. 1 and No. 2 of Project 265, and in Report No. 1, Project 286, AAF School of Aviation Medicine. The testing procedure may be briefly described as follows: Four instrument dial assemblies, mounted in a row on a masonite panel, are exposed in an irregular sequence which is the same for each subject. The two dials whose relative legibilities are being measured are always placed centrally. In each comparison half of the subjects are tested with a particular dial in the left central position and half of the subjects are tested with that dial in the right central position. The two outside positions are filled with carburetor temperature indicators. The subject is thus required to identify the type of scale he is reading as well as the numerical value of the setting. Each subject is required to read a total of 160 dial settings, or 40 settings on each of the four dials. The first 12 settings comprise a preliminary practice series with an exposure time of 4-seconds. The next 68 trials, with an exposure time of 1.5-seconds, are considered to constitute an additional practice series which prepares the subjects for the short interval readings in the last and crucial series. The last series of 80 trials with 20 settings per dial and an exposure interval of .75-seconds provides the critical data for evaluating the relative legibility of the two dials being compared. The subjects employed in this study consisted of qualified aircrew trainees with 10-hours or less of pilot training and no specific instrument instruction. Naive subjects were not available for all of the measurements so that in certain comparisons subjects were employed who had taken part in the dial reading project several weeks before. In no case, however, had any subject who was employed in this experiment on manifold pressure indicators been previously tested on this class of dial.

Results

The appendix contains detailed quantitative measurements for 10 comparisons of the relative legibility of various dial assemblies. In all cases the subjects were required to read the manifold pressure dials to the nearest 1/2 inch. In scoring the records, a reading which does not differ from the calibration by more than plus or minus one division is considered to be correct. The quantitative findings may be enumerated as follows:

Comparison No. 1 (See Fig. 1): Incandescent light. 20 experienced subjects. Type 1 dial (Standard manifold pressure dial, AC Type D-10) vs. modified dial, Type 2, with 1/8 inch numbers at the mid-division marks obscured. With incandescent light there is no significant difference in the relative legibility of these two dials.

Comparison No. 2 (See Fig. 1): Ultraviolet light. 20 experienced subjects. Type 1 dial (see above) vs. Type 2 dial (see above). Experienced subjects do not register a statistically significant difference in the relative legibility of these two dials under conditions of ultraviolet light.

Comparison No. 2a (See Fig. 1): Ultraviolet light. 20 inexperienced subjects. Type 1 dial (see above) vs. Type 2 dial (see above). The modified dial which has the mid-division figures obscured is superior to the standard dial.

Comparison No. 2b (See Fig. 1): Ultraviolet light. 20 experienced subjects and 20 inexperienced subjects from the above groups. Type 1 dial (see above) vs. Type 2 dial (see above). At an exposure interval of .75 seconds, the standard dial causes more errors than the dial with the mid-division numbers obscured.

Comparison No. 3 (See Fig. 2): Incandescent light. 20 inexperienced subjects. Type 1 dial (AC type D-10) vs. Type 3 dial with 3/16 inch x 1/32 inch numbers at each five-inch division mark. The Type 1 or standard dial exhibits a statistically significant superiority to Type 3 dial with the smaller and more uniform figures.

Comparison No. 4 (See Fig. 3): Incandescent light. 20 inexperienced subjects. Type 3 dial with 3/16 inch numbers at each five-inch division mark and the starting point of the scale in the 8 o'clock position vs. Type 4 dial with 3/16 inch figures and the starting point of the scale in the 6 o'clock position. There is no statistically significant difference between the relative legibility of the two dials. Apparently the position of the starting point of this scale can be shifted considerably without affecting the overall legibility of the dial.

Comparison No. 5 (See Fig. 3): Ultraviolet light. 20 inexperienced subjects. Type 3 dial (see just above) vs. Type 4 dial (see just above). There is no statistically significant difference between the relative legibility of the two dials under ultraviolet light.

Comparison No. 6 (See Fig. 4): Incandescent light. 20 inexperienced subjects. Type 4 dial with 3/16 inch numbers at each five-inch division mark and the starting point of the scale in the 6 o'clock position vs. Type 5 dial (AC Type D-8) with 3/16 inch numbers at each five-inch division mark and the starting point of the scale in the 6 o'clock position. Scale range on Type 4 dial is 10-75. Scale range on Type 5 dial is 10-50. Type 5 dial with the shorter scale (10-50) yields a significantly fewer number of errors than the Type 4 dial (10-75 scale).

Comparison No. 7 (See Fig. 5): Incandescent light. 20 inexperienced subjects. Type 5 dial (AC Type D-8) with 3/16 inch numbers at each five-inch division mark and the starting point of the scale in the 6 o'clock position vs. Type 6 dial (AC Type D-8A) with 3/16 inch numbers at each five-inch division mark and the starting point of the scale in the 6 o'clock position. Scale range on Type 5 dial is 10-50. Scale range on Type 6 dial is 10-60.

Type 5 dial with the shorter scale (10-50) yields a significantly smaller number of errors than the Type 6 dial (10-60 scale). That is to say, a scale with divisions spaced at approximately 8° gives significantly fewer errors than a scale with division marks at 6° 25' 44.4". In other words, a difference of approximately a degree and one-half in the spacing of the division lines for two dials being compared yields a significant difference in the relative legibility of the two dials.

Comparison No. 8 (See Fig. 6): Incandescent light. 20 inexperienced subjects. Type 7 dial (Standard fuel pressure dial, AC Type C-14A) with a scale range of 0-25 vs. Type 5 dial (Standard manifold pressure dial, AC Type D-8) with a scale range of 0-50. Subjects were required to read both dials in the same terms, i.e., to the nearest 1/2 inch of pressure. Few errors were made on either of the above dials and no significant difference in the relative legibility of the two instruments could be demonstrated.

Comparison No. 9 (See Fig. 2): Incandescent light. 20 experienced subjects. Type 1 dial (AC Type D-10) vs. Type 3 dial with 3/16 inch x 1/32 inch numbers at each five-inch division mark. Both dials have modified pointers with uniform taper starting 5/16 inch from the tip in contrast with the standard hands shown in Fig. 2 which have a taper starting 1/8 inch from the tip. The substitution of a pointer with less tendency to obscure the numbers of Type 3 dial and the small mid-division numbers of Type 1 dial has not altered the direction of the differences in relative legibility. Type 1 dial, with the large figures, again exhibits a statistically significant superiority to Type 3 dial which has the smaller and uniform figures. It is of interest, perhaps, that a majority of the subjects in this comparison and in Comparison No. 3, preferred the dial with the larger figures to the one with the smaller and uniform figures.

Summary and Discussion of Results

With ultraviolet light the standard manifold pressure indicator dial (AC Type D-10) exhibits an improved legibility when the small numbers at the mid-division marks are obscured. The reports of the subjects employed in this experiment and similar evidence from tachometer dial studies suggest that the small numbers at the mid-division, which are somewhat difficult to interpret with ultraviolet excitation, serve to distract the subject momentarily so that his ultimate responses tend to be slowed up. This confirms the conclusion formulated in previous studies of this project, namely, that the 'cleaner' the dial the more legible it proves to be. The findings also suggest that the ultraviolet illumination tends to create the more critical situation or limiting condition.

In contrast with the previously reported findings of the second tachometer dial study (See Report No. 2, Project 265, AAF School of Aviation Medicine), the manifold pressure dial with the 1/4 inch figures is superior to a dial with 3/16 inch figures. This cannot be attributed to the fact that a standard width pointer tends to obscure a greater proportion of the

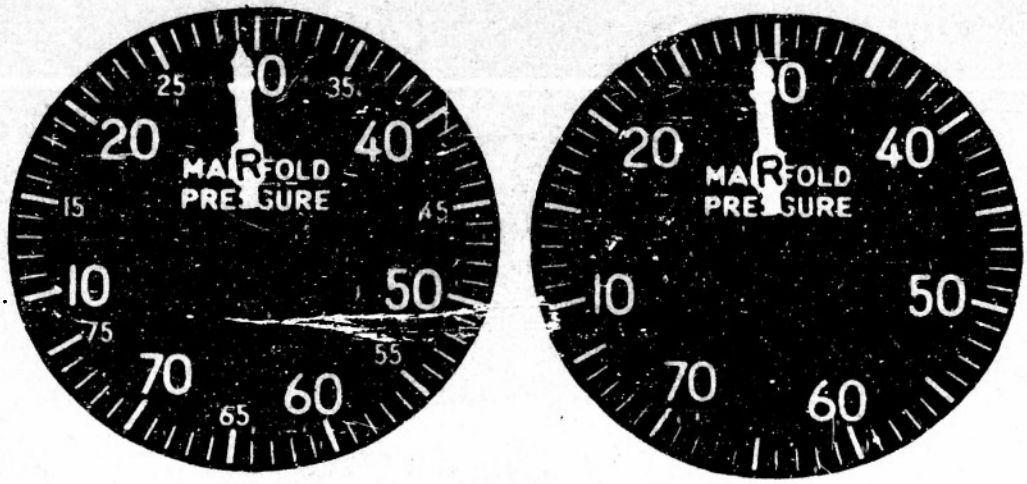
small figures than of the large figures. A specific check, made with a specially tapered pointer which has only a minimal tendency to obscure the smaller numbers, yields the same type of findings as were obtained from pointers with standard tips. The apparent discrepancy between the relative legibility of a tachometer dial with large figures and the relative legibility of a manifold pressure indicator with large figures can probably be accounted for in terms of the different styles of numerals which are employed in the two instances. As it was pointed out in the second research report on tachometer dials, the style of the numerals engraved on the tachometer dial makes it difficult to tell which division the large figures are to be associated with. In the present instance, the ratio of the height to width of the large numerals engraved on the manifold pressure dial (i.e., a ratio greater than 1.00) tends to obviate this difficulty.

A manifold pressure dial which has its starting point in the 8 o'clock position does not give rise to any more errors than a dial which has its starting point in the 6 o'clock position. It would appear that the starting point of the dial's scale can be shifted considerably without affecting its legibility.

Within certain limits, the legibility of a dial appears to be closely associated with the angular spacing of the division marks. Thus a dial with a range of 10-50 is significantly more legible than a scale which covers the same portion of the dial's circumference but has a range of 10-60. The actual difference in the angular spacing of the division marks in this instance is only about one and one-half degrees. On the other hand, when the dial with a scale of 10-50 is compared with a dial having a scale of 0-25 covering the same portion of the circumference there is no measurable difference in relative legibility with incandescent light. In other words, once the dial scale has reached a certain degree of expansion, further simplification does not appear to affect its legibility.

APPENDIX

Figure 1. Comparison No. 1. Incandescent light. Type 1 dial vs. Type 2 dial. 20 experienced subjects, 400 judgements at .75 seconds.



Type 1 Dial — 5% error

Type 2 Dial — 4% error

No statistically significant difference (T-value, .71)

See Fig. 1. Comparison No. 2. Ultraviolet light. Type 1 dial vs. Type 2 dial. 20 experienced subjects, 400 judgements at .75 seconds.

Type 1 Dial — 15% error

Type 2 Dial — 11% error

No statistically significant difference (T-value, 1.67)

See Fig. 1. Comparison No. 2a. Ultraviolet light. Type 1 dial vs. Type 2 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.

Type 1 Dial — 12% error

Type 2 Dial — 7% error

Significant difference at 2% level (T-value, 2.46)

See Fig. 1. Comparison No. 2b. Ultraviolet light. Type 1 dial vs. Type 2 dial. 20 experienced and 20 inexperienced subjects from above groups. 800 judgements at .75 seconds.

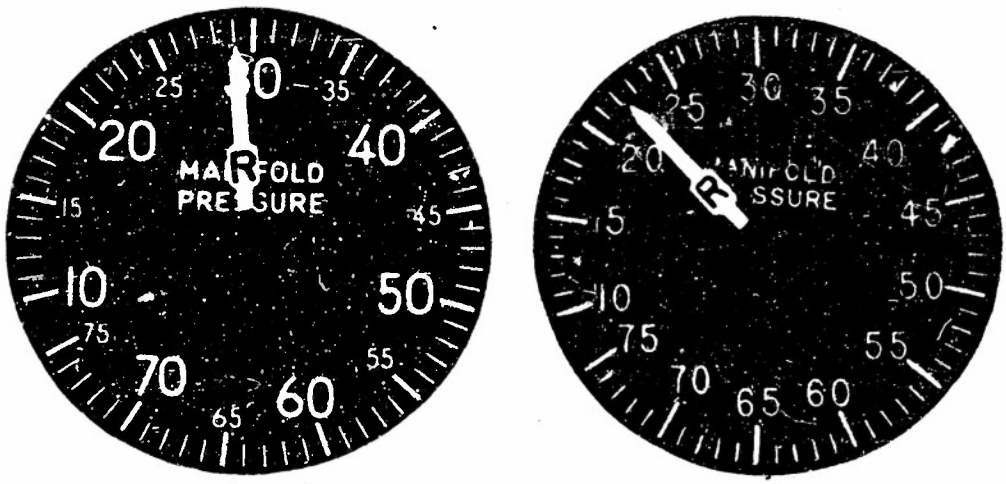
Type 1 Dial — 13% error

Type 2 Dial — 8% error

Significant difference at 1% level (T-value, 3.13)

APPENDIX

Figure 2. Comparison No. 3. Incandescent light. Type 1 dial vs. Type 3 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.

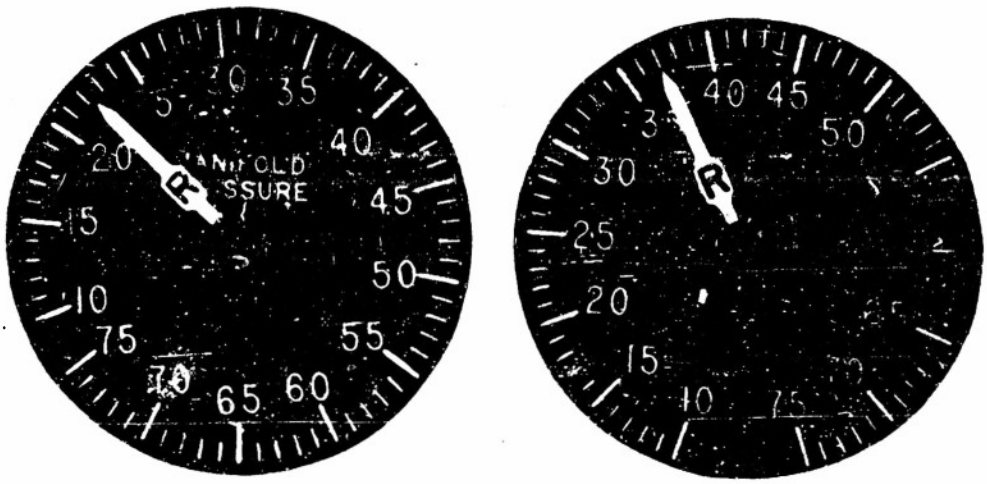


Type 1 Dial
6% error

Type 3 Dial
15% error

Significant difference at 1% level (T-value, 4.29)

Figure 3. Comparison No. 4. Incandescent light. Type 3 dial vs. Type 4 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.



Type 3 Dial
18% error

Type 4 Dial
16% error

No statistically significant difference (T-value, .74)

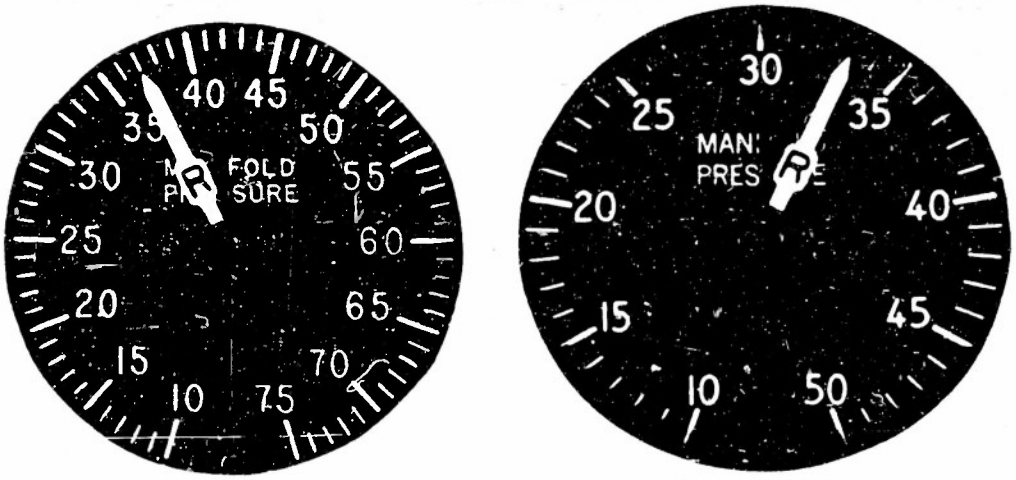
APPENDIX

See Fig. 3. Comparison No. 5. Ultraviolet light. Type 3 dial vs. Type 4 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.

Type 3 Dial	Type 4 Dial
40% error	36% error

No statistically significant difference (T-value, 1.17)

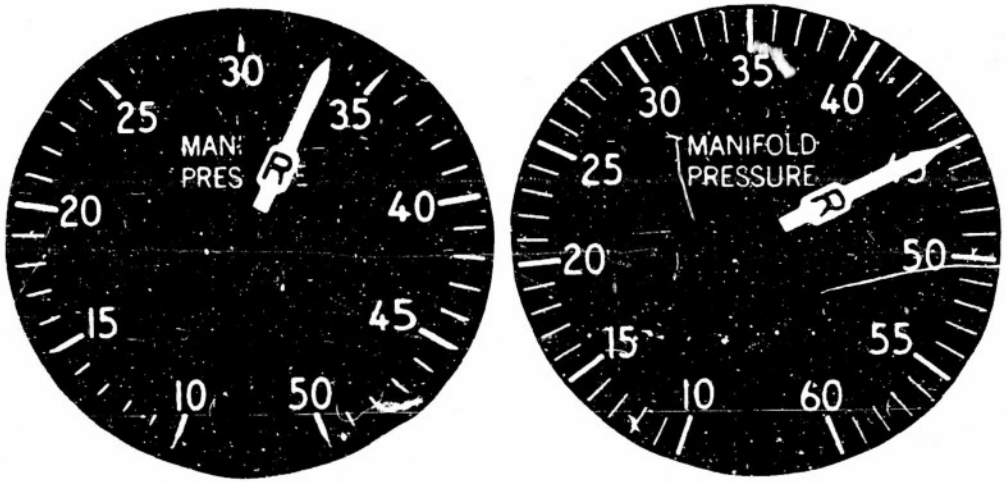
Figure 4. Comparison No. 6. Incandescent light. Type 4 dial vs. Type 5 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.



Type 4 Dial	Type 5 Dial
20% error	12% error

Significant difference at 1% level (T-value, 3.08)

Figure 5. Comparison No. 7. Incandescent light. Type 5 dial vs. Type 6 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.



Type 5 Dial	Type 6 Dial
12% error	21% error

Significant difference at 1% level (T-value, 2.96)

APPENDIX

Figure 6. Comparison No. 8. Incandescent light. Type 5 dial vs. Type 7 dial. 20 inexperienced subjects, 400 judgements at .75 seconds.

Type 5 Dial
11% error

Type 7 Dial
9% error

No statistically significant difference (T-value, 1.20)

See Fig. 2. Comparison No. 9. Incandescent light. Type 1 dial vs. Type 3 dial. Modified pointers on both dial with uniform taper starting 5/16" from tic, in contrast with hands shown in Figure 2. 20 experienced subjects, 400 judgements at .75 seconds.

Type 1 Dial
1% error

Type 3 Dial
6% error

Significant difference at 1% level (T-value, 4.13)